

## **METHOD OF DEFLAVORING SOY-DERIVED MATERIALS FOR USE IN DOUGH-BASED AND BAKED PRODUCTS**

The present application is a continuation-in-part application of United States Patent Application Serial Number 09/939,500, filed August 23, 2001, which was based on, and claimed benefit of, United States Provisional Application Serial Number 60/250,228, filed on November 30, 2000, both of which are hereby incorporated by reference.

### **BACKGROUND OF THE INVENTION**

This invention relates generally to the processing of soy-derived materials for use in various food products, especially dough-based and baked products. More particularly, the invention relates to a method of deflavoring soy materials in order to make them acceptable in a wide range of foods, including dough-based and baked products.

In recent years, soy proteins have become widely used in food products, for the health benefits to be obtained from their use. In some applications, the taste of the soy materials is not objectionable. However, in some uses, such as dairy analog products, beverages and the like, the flavors found in soy materials may prevent their ready acceptance by the consumer. Thus, in order to extend the uses of soy materials, the present inventors wanted to find a method of reducing the flavor components of soy materials. However, it was not evident that methods which had been used previously to remove flavor components from other organic materials would be successful in the treating of soy materials. Organic materials, since they have complex compositions, must be tested to determine whether any given method of treating them will be satisfactory.

One example of previously employed methods to purify organic materials is found in U.S. Patent 4,477,480, in which the patentees show that starch can be treated with an alkali to remove objectionable flavor components. In a commonly assigned patent, U.S. Patent 4,761,186, ultrafiltration is used to purify starch. In both cases, flavor components are

removed from the starch, in the '480 patent by solubilizing the flavor components so that they can be washed out of the relatively insoluble starch. In the '186 patent, ultrafiltration was used to remove the flavor components as permeate, while the insoluble starch remained in an aqueous slurry. By  
5 contrast, the present invention separates flavor components from soluble high molecular weight soy proteins.

There are many articles and patents which relate to processing soy materials in order to recover the protein content and which at the same time reduce the flavor compounds to make the proteins more acceptable in food  
10 products. However, these previous disclosures were not specifically directed to removal of flavoring compounds and recovering as much of the protein as possible. One example is U.S. Patent 4,420,425 in which protein components of soy are solubilized at a pH of 7 to 11, preferably about 8 and, after ultrafiltration through a membrane having a molecular weight cut off  
15 above 70,000, are recovered by spray drying the retained soy proteins. In variants, only a portion of the protein is solubilized at lower pH values and subjected to ultrafiltration with a membrane having a cutoff preferably above 100,000 molecular weight, the product was found to have improved color and flavor. A higher cutoff valve would be expected to result in a loss of valuable  
20 proteins. In another patent, U.S. Patent 5,658,714, a soy flour slurry is pH-adjusted to the range of 7 to 10 to solubilize proteins, which are then passed through an ultrafiltration membrane and phytate and aluminum are retained, presumably as solids. While the molecular weight cutoff of the membrane was not given, it is assumed that the pore size was large in order to be able to  
25 pass the soluble proteins. Both of these patents contain extensive discussions of the efforts of others in the processing of soy materials; neither teaches or suggests the control of pH during the ultrafiltration process.

In a group of related patents, Mead Johnson Company disclosed processes for solubilizing soy proteins by raising the pH of an aqueous  
30 solution of soy materials and recovering the proteins which are said to have a bland taste. The processes are principally directed to concentrating proteins

rather than removing flavor compounds. In U.S. Patent 3,995,071, the pH was increased to 10.1 to 14 (preferably 11 to 12) to solubilize soy proteins, after which the pH was lowered to about 6 to 10 and ultrafiltration with a membrane having a molecular weight cutoff of 10,000 to 50,000 Daltons was used to retain the proteins while discarding carbohydrates and minerals. In 5 U.S. Patent 4,072,670, emphasis was placed on removing phytates and phytic acid by solubilizing proteins at a pH of 10.6 to 14 and a temperature of 10 to 50°C to make the phytates and phytic acid insoluble, then separating them and finally acidifying the solution to a pH of about 4 to 5 to precipitate 10 the soy proteins. In U.S. Patent 4,091,120 soy proteins were solubilized at a pH less than 10, preferably 7 to 9 and ultrafiltration was used to separate the proteins as retentate, while passing carbohydrates as permeate. These patents do not teach or suggest control of the pH during the ultrafiltration process.

15 The present inventors wanted to remove compounds in soy materials which contribute color and flavor and which interfere with the use of soy in certain food products such as beverages, dairy analogs, and the like. They have found that soy-derived materials can be treated successfully using the process to be described below, recovering substantially all of the proteins and 20 rejecting the compounds which cause undesirable color and flavor. Moreover, by controlling the pH within the range of about 9 to about 12 during the ultrafiltration process, deflavored soy materials having improved functional properties can be obtained. Thus, the product is suitable for many food products.

## 25 SUMMARY OF THE INVENTION

Broadly, the invention is a process for preparing an aqueous soy composition having a soy concentration of about 1 to about 20 percent, which is pH-adjusted to solubilize the protein content and to release the flavoring compounds. Then the composition is subjected to ultrafiltration, while 30 maintaining pH control, using a membrane capable of retaining substantially

all of the protein content of the soy while removing flavoring components as permeate.

The deflavored soy materials prepared by the present methods are ideally suited for use in dairy and non-dairy beverages, smoothies, health  
5 drinks, confectionary type products, nutritional bars, cheeses, cheese analogs, dairy and non-dairy yogurts, meat and meat analog products, cereals, baked products, snacks, and the like. Especially preferred baked products include pizza crust, cookies, crackers, cereals (flakes, puffed, and the like), and the like. Such preferred baked products are generally prepared  
10 by incorporating the deflavored soy materials prepared by the methods described herein into a conventional dough.

In one embodiment, the present invention provides a soy-containing dough comprising a flour-based dough and a deflavored soy protein material, wherein the deflavored soy protein material is prepared by a method  
15 comprising:

(a) preparing an aqueous composition of a soy material containing soluble soy proteins, flavoring compounds, and insoluble materials;

(b) solubilizing the soy proteins by adjusting the aqueous composition of (a) to a pH in the range of about 9 to about 12 and releasing the flavoring  
20 compounds;

(c) passing the pH-adjusted aqueous composition of (b) adjacent an ultrafiltration membrane having a molecular weight cutoff up to about 50,000 Daltons, while maintaining the pH in the range of about 9 to about 12, under suitable ultrafiltration conditions wherein the flavor compounds pass through  
25 the membrane, thereby deflavoring the soy material and retaining substantially all of the solubilized soy proteins; and

(d) recovering the solubilized soy proteins retained by the ultrafiltration membrane, wherein the recovered solubilized soy proteins is the deflavored soy protein material.

30 In another embodiment, the present invention provides a soy-containing baked product comprising product prepared from a flour-based

dough containing a de-flavored soy protein material, wherein the de-flavored soy protein material is prepared by a method comprising:

(a) preparing an aqueous composition of a soy material containing soluble soy proteins, flavoring compounds, and insoluble materials;

5 (b) solubilizing the soy proteins by adjusting the aqueous composition of (a) to a pH in the range of about 9 to about 12 and releasing the flavoring compounds;

(c) passing the pH-adjusted aqueous composition of (b) adjacent an ultrafiltration membrane having a molecular weight cutoff up to about 50,000  
10 Daltons, while maintaining the pH in the range of about 9 to about 12, under suitable ultrafiltration conditions wherein the flavor compounds pass through the membrane, thereby de-flavoring the soy material and retaining substantially all of the solubilized soy proteins; and

(d) recovering the solubilized soy proteins retained by the ultrafiltration  
15 membrane, wherein the recovered solubilized soy proteins is the de-flavored soy protein material.

In another embodiment, the present invention provides a method of preparing a soy-containing baked product containing a de-flavored soy protein material, said method comprising

20 (1) preparing a soy-containing dough comprising a flour-based dough and a de-flavored soy protein material; and

(2) baking the soy-containing dough to form the soy-containing baked product;

wherein the de-flavored soy protein material is prepared by a method  
25 comprising:

(a) preparing an aqueous composition of a soy material containing soluble soy proteins, flavoring compounds, and insoluble materials;

(b) solubilizing the soy proteins by adjusting the aqueous composition  
of (a) to a pH in the range of about 9 to about 12 and releasing the flavoring  
30 compounds;

(c) passing the pH-adjusted aqueous composition of (b) adjacent an ultrafiltration membrane having a molecular weight cutoff up to about 50,000 Daltons, while maintaining the pH in the range of about 9 to about 12, under suitable ultrafiltration conditions wherein the flavor compounds pass through the membrane, thereby deflavoring the soy material and retaining  
5 substantially all of the solubilized soy proteins; and

(d) recovering the solubilized soy proteins retained by the ultrafiltration membrane, wherein the recovered solubilized soy proteins is the deflavored soy protein material.

10 In one aspect, the invention is a method of deflavoring soy-derived materials such as soy milk, soy flour, soy concentrates, and soy protein isolates, which method includes preparing an aqueous composition of the soy material containing flavoring compounds, adjusting the pH to the range of about 9 to 12 to solubilize the protein content of the soy material and release  
15 the flavor components, and then passing the pH-adjusted composition adjacent to an ultrafiltration membrane having pores which provide a molecular weight cutoff up to 50,000 Daltons, while maintaining the pH in the range of about 9 to about 12, thus retaining substantially all of the protein content, while passing through the pores the flavor producing compounds.

20 In another aspect, the invention includes adjusting the pH to the range of about 9 to about 12 with an alkali such as sodium, potassium or calcium hydroxides to solubilize the protein content and releasing the flavor compounds, making it possible to separate such compounds by ultrafiltration. Importantly, the pH is also controlled within the range of about 9 to about 12  
25 during the ultrafiltration process.

In one embodiment, the invention is a method for deflavoring soy materials in a continuous process wherein a pH-adjusted aqueous mixture of soy materials is passed adjacent an ultrafiltration membrane to separate the flavor components. The pH is maintained at about 9 to about 12 during the  
30 ultrafiltration by the addition of the appropriate amount of an appropriate pH-altering material (generally a base). The permeate containing flavor

components and water is passed adjacent a reverse osmosis membrane to dewater the permeate and the separated water is recycled to join recycled retentate and fresh pH-adjusted soy materials. A portion of the retentate is continually removed and the decaffeinated soy materials recovered.

5           In a preferred embodiment, the invention is a method for decaffeinating soy materials in a batch or semi-continuous process wherein a pH-adjusted aqueous mixture of soy materials is passed adjacent an ultrafiltration membrane, the permeate is separated for recovery of the flavor components, and the retentate is recycled to join fresh pH-adjusted soy materials. Water is  
10 added periodically or continuously to replace the water lost to the permeate and to adjust the concentration of soy materials in the combined stream to a predetermined level. If necessary, a pH-altering material (e.g., a base) can be added to the recycled retentate or added water to control the pH to the desired range during the ultrafiltration process. The process is continued until  
15 all of the flavoring compounds have been removed.

          In another preferred embodiment, the present invention provides a method for preparing decaffeinated soy protein material, said method comprising:

- 20           (a) preparing an aqueous composition of a soy material containing soluble soy proteins, flavoring compounds, and insoluble materials;
- (b) solubilizing the soy proteins by adjusting the aqueous composition of (a) to a pH in the range of about 9 to about 12 and releasing the flavoring compounds;
- (c) removing the insoluble materials from the pH-adjusted aqueous  
25 composition of (b) to obtain a treated aqueous composition;
- (d) passing the treated aqueous composition of (c) adjacent an ultrafiltration membrane having a molecular weight cutoff up to about 50,000 Daltons, while maintaining the pH in the range of about 9 to about 12, under suitable ultrafiltration conditions wherein the flavor compounds pass through  
30 the membrane, thereby decaffeinating the soy material and retaining substantially all of the solubilized soy proteins; and

(e) recovering the solubilized soy proteins retained by the ultrafiltration membran to obtain the deflavored soy protein material.

The ultrafiltration membrane used in the method of the invention will have a molecular weight cutoff up to 50,000 Daltons, preferably 1,000 to 50,000, most preferably about 10,000 and preferably is a polyethersulfone or ceramic membrane.

#### BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a graph of the intensity of soy flavor attributes.

FIG. 2 is a graph of the intensity of deflavored soy milk compared to a control sample.

FIG. 3 is a graph of the intensity of another group of soy flavor attributes.

FIG. 4 is a graph of the intensity of deflavored soy concentrate and a control sample compared to the sample of FIG. 3.

FIG. 5 is a graph of the intensity of deflavored soy concentrate and a control sample.

FIG. 6 is a graph showing the change in concentration of flavor compounds between a deflavored soy sample and a control sample.

FIG. 7 is a graph showing the change in concentration of flavor compounds between a deflavored soy sample and a control sample.

FIG. 8 is a block diagram of one process employing the invention.

FIG. 9 is a graph of the intensity of soy isolate flavor attributes.

FIG. 10 is a graph of the intensity of deflavored soy isolate compared to a control sample.

FIG. 11 is a block diagram of a preferred embodiment for preparing the deflavored soy protein material.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

**Soy-Derived Materials.** Soybeans are valuable sources of oil and, in the present invention, of proteins. Soy beans contain about 40 percent



proteins, which have been classified after ultracentrifugation as 2S, 7S, 11S and 15S (see also U.S. Patent 4,420,425). These fractions may contain other materials as well and they have a wide molecular-weight range, from 3,000 to 600,000. It is well known that soy products have undesirable odors and  
5 flavors which should be removed in order to make the soy materials widely useful in food products. It is believed that lipoxygenases catalyze the oxidation of certain polyunsaturated fatty acids, producing hydroperoxides which are degraded into volatile carbonyl compounds, associated with objectionable odors and flavors in soy-derived materials. Some of the  
10 compounds associated with soy flavors are described in Table C in Example 10 below.

While the protein content of soy-derived materials is considered a valuable fraction for use in food products, soluble carbohydrates are considered undesirable. Their removal from soy protein fractions is an  
15 objective in many processes in which the proteins are recovered.

Phytates are compounds which also are considered undesirable in soy proteins. These compounds are calcium-magnesium-potassium salts of inositol hexaphosphoric acid. Such compounds are believed to chelate metal ions and are not readily absorbed by the human body. They are considered  
20 to bind to soy proteins and interfere with digestion. As mentioned above, removal of phytates has been an objective of workers in the field of soy-derived materials.

**Ultrafiltration Membranes.** Filtration is used to separate many materials. In the present invention, ultrafiltration is used to remove flavoring  
25 compounds from soy-derived materials. Importantly, the pH of the soy-derived material should be maintained in the range of about 9 to about 12 during the ultrafiltration process. Ultrafiltration is intended to remove particles having a size between 10 to 1,000 Angstroms (0.001 to 0.1  $\mu\text{m}$ ), corresponding generally to particles having a molecular weight between  
30 10,000 and 1,000,000, and which may also be affected by the shape of such high molecular weight particles. Soy proteins have molecular range between

about 3,000 and 600,000. A membrane may be chosen which is capable of passing all of the soy proteins or only a selected portion. In the present invention, the soy proteins are retained by the ultra filtration membrane under the selected operating conditions, while the lower molecular weight flavoring compounds pass through the membrane and are separated, thus improving the color and flavor of the retained soy proteins and associated solids.

A polymer ultrafiltration membrane may be defined as an anisotropic (non-uniform) layer. One face is a skin containing pores which determine the size of molecules which can pass through the membrane. Supporting the surface skin is a spongy structure which extends to the opposite face. Such membranes are commonly made by coagulation of polymers in an aqueous bath. Typical polymers which are used include polysulfones, cellulose esters, poly(vinylidene fluoride), poly (dimethylphenylene oxide), poly (acrylonitrile), which can be cast into membranes. Often, the membranes are formed into hollow tubes which are assembled into bundles, through which the solution to be filtered is passed. Alternatively, flat membrane sheets and spiral designs may be used. In commercial practice, pressure is applied to facilitate movement of the lower molecular weight compounds through the membrane. The membrane must be able to withstand the pressures used, making it important that the spongy supporting structure be uniform to avoid breaking the surface skin and bypassing the membrane.

In addition to the polymeric membranes just described, other materials have been used to make ultrafiltration membranes, such as ceramics, sintered metals, and other inorganic materials. The present invention is not limited to any particular type of membrane. In general, the membrane must be able to pass the flavoring compounds, which are believed to have molecular weights lower than 1,000 Dalton. More importantly, the membranes must be able to retain substantially all of the solubilized soy proteins. Thus, the membrane of the invention will have a molecular weight cutoff up to about 50,000 Daltons, preferably about 1,000 to 50,000, more preferably 10,000 to 30,000.

**Process.** The process of the invention includes the following steps:

(1) Prepare an aqueous mixture of the soy-derived material;

(2) Add a base to raise the pH of the aqueous mixture to about 9 to about 12 in order to solubilize the soy proteins and to release the flavoring compounds;

(3) Pass the pH-adjusted mixture, while maintaining the pH in the range of about 9 to about 12, adjacent to an ultrafiltration membrane having a molecular weight cutoff up to about 50,000 Daltons, remove the flavoring compounds as permeate, and remove the remaining soy proteins and other soy materials as retentate; and

(4) Neutralize the retentate and recover the soy proteins.

All types of soy materials are considered to be potential sources of soy for use in food products. Thus, soy materials which contain proteins are combined into an aqueous mixture, generally a slurry of soy solids. The protein content is needed for food products, but as discussed above, it is believed to contain flavoring compounds which must be released in order that they can be separated. The separation of flavoring compounds is carried out in an aqueous mixture in which both the proteins and flavoring compounds are dissolved. The concentration of the soy materials in the aqueous mixture will be in the range of about 1 to about 20 percent. Generally, the concentration of soy materials after pH adjustment will change during the subsequent ultrafiltration step as water is removed with the permeate. The water will be replaced either periodically or continuously. For example, in diafiltration water is added to gradually dilute the retained proteins in a batch or semi-continuous process.

The second step, as will be seen in the examples, is important if removal of the flavoring compounds is to be accomplished. The soy proteins are solubilized by adding a base to the aqueous mixture to achieve a pH of about 9 to 12. In general, it has been found that a pH of 9 is needed to solubilize all of the proteins, while a pH higher than 12 is likely to cause undesirable degradation of the proteins. While in theory any base might be

used, sodium or potassium hydroxide are preferred, particularly potassium hydroxide. Other bases which may have application include calcium, magnesium and ammonium hydroxides. It is believed that solubilizing the soy proteins changes their shape and in some manner results in releasing the  
5     flavoring compounds, which may be bound or encapsulated by the soy proteins when they are in a neutral or acid solution. The flavoring compounds, which have relatively low molecular weight compared to the soy proteins are able to pass through the pores of the ultrafiltration membrane, while substantially all of the solubilized soy proteins are too large and are  
10    retained. Importantly, the pH should be maintained within the just described range (i.e., about 9 to about 12) during the ultrafiltration/diafiltration process to allow as much of the flavoring compounds as possible to be removed.

      The third step could be carried out in a batch manner similar to the laboratory experiments reported below in Examples 1-5 in which the flavor  
15    compounds and water passed through the membrane and were removed by flowing water. However, in commercial applications of the process of the invention, the pH-adjusted aqueous mixture would be circulated continuously adjacent to an ultrafiltration membrane. Since water, the caustic and the flavoring compounds pass through the membrane as permeate and are  
20    discarded, additional water will be added to maintain the desired concentration of soy materials, which will tend to lower the pH of the aqueous mixture. This water may be augmented by dewatering the permeate and recycling the recovered water to the feed stream. A pH-modifying material (e.g., base) can be added as necessary to control the pH in the desired range  
25    (i.e., about 9 to about 12) directly to the ultrafiltration solution, to any recycled aqueous material, or to makeup water as desired.

      After removal of the flavoring compounds (i.e., after completion of the ultrafiltration process), further neutralization of the filtered solution may be accomplished by withdrawing product and adding an acid as required to  
30    reach the desired pH. After pH adjustment, the aqueous mixture of soy

proteins and other materials may be used directly in food products, or it may be concentrated or dried as required for the intended use.

A process for deflavoring soy materials by ultrafiltration may be operated in various ways. The pH during the ultrafiltration/diafiltration process is maintained in the range of about 9 to about 12, and preferably in the range of about 9.5 to about 10.5. Two methods will be described, continuous processing and batch (including semi-continuous operation) processing. It is expected that commercial processes will adopt batch or semi-continuous operation, which should be better suited to production of food-grade soy products. A continuous process is generally shown in FIG. 8. In either a continuous or batch process an aqueous mixture of soy materials is pH adjusted to solubilize soy proteins and release flavor compounds and then passed adjacent an ultrafiltration membrane which permits the lower molecular weight flavoring materials to pass through its pores along with water (the permeate), leaving the higher molecular weight soy materials (the retentate) to be recirculated. A portion of the retentate will be withdrawn as deflavored product, from which the soy materials can be recovered as needed for the ultimate end use. Water will be added to replace that lost in the permeate and to provide a constant concentration of soy materials in the feed stream supplied to the ultrafiltration membrane. Although not essential to the process, the process of FIG. 8 includes additional processing of the permeate to recover a portion of the water using a reverse osmosis membrane for recycling to join the retentate and fresh soy materials. The advantage of such a step is in reducing the amount of fresh water which must be added to the process and removed in concentrating the permeate. Of course, the pH of the soy-derived materials can be kept within the desired range by appropriate addition of a base to the recycled or fresh water added to the process or by direct addition of base as desired.

In a batch process, such as those described in Examples 6-8 below, a batch of soy material is placed in a vessel, pH adjusted, and fed to an ultrafiltration membrane. The permeate is separated and the retentate is

returned to the vessel. As the process proceeds, the soy material is depleted in the lower molecular weight flavoring compounds and water and becomes more concentrated in the desirable soy proteins. Periodically, water is added to the retentate to dilute it and provide a carrier for the flavoring compounds which are passed through the membrane. In a semi-continuous process the water is added continuously at the rate it is being removed in the permeate. The process is continued until all of the flavoring compounds have been removed and the retentate is sufficiently deflavored to become the product, which can be further processed as required for the ultimate end use. A batch or semi-continuous process may also include the concentration of the permeate, with recycle of separated water in a similar manner as that shown in FIG. 8. The pH during the ultrafiltration/diafiltration process is maintained in the range of about 9 to about 12, and preferably in the range of about 9.5 to about 10.5.

The ultrafiltration membrane will be operated with a pressure differential across the membrane which assists migration of the flavoring compounds, water and other materials which are capable of passing through the pores of the membrane, while not exceeding the physical strength of the membrane. Typical average pressure for such membranes are about 50 psi (345 kPa). The trans-membrane pressure (in versus out) will be about 15 psi (103 kPa). Of course, these pressures could be varied based on the membrane's specifications and other operational concerns. The flow rate of the feed stream will provide sufficient residence time for significant permeate removal, but also will be high enough to provide turbulence so that the access of the feed stream to the membrane pores will not be hindered by solid deposits on the membrane walls. One skilled in the art will understand that suitable operating parameters will be determined by experience with the materials being separated.

In a preferred embodiment, the present invention provides a method for preparing deflavored soy protein material, said method comprising: (a) preparing an aqueous composition of a soy material containing soluble soy

proteins, flavoring compounds, and insoluble materials; (b) solubilizing the soy proteins by adjusting the aqueous composition of (a) to a pH in the range of about 9 to about 12 and releasing the flavoring compounds; (c) removing the insoluble materials from the pH-adjusted aqueous composition of (b) to  
5 obtain a treated aqueous composition; (d) passing the treated aqueous composition of (c) adjacent an ultrafiltration membrane having a molecular weight cutoff up to about 50,000 Daltons, while maintaining the pH in the range of about 9 to about 12, under suitable ultrafiltration conditions wherein the flavor compounds pass through the membrane, thereby deflavoring the  
10 soy material and retaining substantially all of the solubilized soy proteins; and (e) recovering the solubilized soy proteins retained by the ultrafiltration membrane to obtain the deflavored soy protein material. This preferred embodiment is described in more detail in copending U.S. Patent Application Serial Number \_\_\_\_\_ (Docket 77022), filed on the same day as the present  
15 application, and which is hereby incorporated by reference.

This preferred embodiment is illustrated in FIG. 11 wherein the pH of an aqueous solution of soy protein is adjusted to about 9 to about 12. The pH-adjusted aqueous solution is then treated to remove insoluble materials. Any conventional technique (e.g., filtration, decantation, centrifugation, and  
20 the like) can be used. Preferably, the insoluble material is removed by centrifugation. Commercial available continuous centrifugation units are ideally suited for this separation in a semi-batch or continuous type operation. In an especially preferred embodiment, the pH-adjusted aqueous is subjected to the removal technique (e.g., centrifugation) at least twice in order facilitate  
25 or more complete removal of insoluble materials. The treated supernatant is then subjected to ultrafiltration, preferably combined with diafiltration, in order to remove the flavor components normally associated with soybeans. During ultrafiltration, the pH of the soy-derived material should be maintained in the range of about 9 to about 12. After ultrafiltration, the pH is adjusted to a  
30 neutral pH using an edible acid (e.g., citric acid). The deflavored soy protein solution may be used directly or it may be converted to a solid form if desired.

Any conventional technique for removing water can be used. Generally, spray or freeze drying techniques are preferred.

**De-flavored Soy Products.** The de-flavored soy materials prepared by the present methods are ideally suited for use in dairy and non-dairy beverages, smoothies, health drinks, cheeses, cheese analogs, dairy and non-dairy yogurts, meat and meat analog products, cereals, baked products, snacks, and the like. Especially preferred baked products include pizza crust, cookies, crackers, cereals (flakes, puffed, and the like), and the like. Such preferred baked products are generally prepared by incorporating the de-flavored soy materials prepared by the methods described herein into a conventional dough.

Although solid forms of the de-flavored soy materials (e.g., soy protein isolate or concentrates) are preferably used, aqueous solutions or slurries of the de-flavored soy materials can also be used so long as the amount of water used to prepare the dough is adjusted to take into account the water added with the aqueous soy material solutions or slurries. Dough containing up to about 30 percent soy protein isolate or concentrate can be used in the present invention. More preferably, the dough contains about 5 to about 25 percent of a solid form of soy protein isolate or concentrate. The soy-containing dough can be baked using conventional techniques and equipment to prepare the de-flavored soy protein baked products of this invention.

Unless noted otherwise, all percentages are by weight.

**EXAMPLE 1.** Soy protein isolate (Protein Technology International (PTI); St. Louis, MO) was hydrated in tap water to provide a concentration of 10 percent. The aqueous composition was mixed with a magnetic stirrer until all of the soy protein isolate was completely dispersed. The pH of the mixture was adjusted to 11.0 using sodium hydroxide. Then, the pH-adjusted composition was placed in a dialysis tube (Spectrum, Inc.) having a 3500 molecular weight pore size and tap water was passed over the outside of the tube continuously for about 4 hours; the pH remained greater than about 9 during dialysis. The composition remaining in the dialysis tube was poured



into a glass beaker, neutralized, and evaluated for aroma and taste. A comparison was made with the dialyzed composition and a sample treated in a similar manner, but which had a pH of 6.7 and a second sample which had been neither dialyzed nor pH-adjusted. Blind evaluation by several  
5 individuals showed that only the pH-adjusted and dialyzed sample had significantly improved taste and aroma.

**EXAMPLE 2.** A similar test was carried out using soy milk (Devansoy Farms, Carrol, Iowa) made into a 10 percent aqueous composition and then pH-adjusted and dialyzed overnight as in Example 1. After the treatment, the  
10 pH of the sample was 8.8 and the aroma and taste were significantly improved.

**EXAMPLE 3.** Example 2 was repeated with soy milk freshly prepared by soaking and blanching the beans and then grinding and separating the soy milk from the meal. After pH adjustment and dialysis as previously described,  
15 it was found that the taste and aroma of the soy milk was significantly improved.

**EXAMPLE 4.** Example 3 was repeated using a dialysis tube having a pore size of 6000 molecular weight and similar results were obtained.

**EXAMPLE 5.** Example 2 was repeated with dry soy flour (Cargill).  
20 The soy flour was hydrated to a 10 percent composition and then pH-adjusted as previously described. After dialyzing overnight the pH of the remaining composition in the dialysis tube had a pH of 8.7 and had significantly improved aroma and taste.

**EXAMPLE 6.** In a large mixing tank 33 pounds (15 kg) of Sun Rich  
25 soy milk containing 15 percent solids was diluted with 66 pounds (30 kg) of water to produce a slurry of 100 pounds (45 kg) containing 5 percent soy solids. A 1N NaOH solution was added slowly to solubilize the soy proteins until a pH of 11 was reached.

A diafiltration of the alkalinized soy solution was carried out by pumping  
30 the solution from the mixing tank through two parallel hollow fiber membranes (A/G Technology Corporation) having a molecular weight cutoff of 10,000

Daltons and a surface area of 3.3 m<sup>2</sup>. The pH was maintained at about 9 to about 12 during diafiltration. The trans-membrane pressure across the membranes was 20-50 psi (138-345 kPa). The material passed through the membrane (permeate) was collected. The remaining material (retentate) was continuously recycled to the mixing tank. When 50 pounds (22.7 kg) of permeate had been collected, the mixing tank contained 50 pounds (22.7 kg) of soy solution. An additional 50 pounds (22.7 kg) of water was added to the mixing tank. This washing with addition of water to the mixing tank was repeated five times, after which the solution in the mixing tank was concentrated to about 10 percent solids as water was removed in the permeate and then the retained soy solution was neutralized with 2 percent citric acid to a pH of 7.0.

The neutralized solution was evaluated by a trained sensory panel and compared with a control sample of Sun Rich soy milk which had been diluted to 10 percent with water, but not otherwise treated. The soy solutions were presented in a blind and randomized order. The results are shown in the graphs of FIGS. 1 and 2.

FIG. 1 shows the mean intensity score for 10 attributes. The panel judged certain attributes to be more significant than others. When compared to the soy solution which had been treated as described above, the outstanding attributes had all been reduced with a 95 percent confidence level. Those attributes which had less prominent in the control (i.e., Brown, Sweet, Sour, Salt and Bitter) were reduced, except for Sweet which increased in value, but the panel mean values did not reach a 95 percent confidence level.

It is clear from the results that the soy solution had been rendered more neutral in flavor by removal of flavor components.

**EXAMPLE 7.** Ten pounds (4.55 kg) of a soy protein concentrate (Central Soya) was mixed with 190 pounds (86.4 kg) of water in a tank with high agitation for 15-30 minutes to hydrate the soy protein. Then 1 N NaOH was added to solubilize the soy protein to a pH of 11. In a similar manner to

that described in Example 6 the soy slurry was pumped through a spiral membrane (Gea Niro Inc.) having a molecular weight cutoff of 10,000 Daltons. The trans-membrane pressure across the membrane was maintained below 50 psi (344.7 kPa) and the pH was maintained at about 9 to about 12. The pressure drop through the membrane was maintained below 15 psi (103.4 kPa). As in Example 6, five additions of water were made when the permeate withdrawn from the membrane reached one-half of the original volume in the mixing tank. After five water additions the pH of the washed soy solution was adjusted to 7.5 by adding 0.5 N HCl and then freeze dried for sensory evaluation.

The deflavored soy protein concentrate was evaluated for six attributes by a trained sensory panel. The mean values for each attribute for the control sample (untreated) are given in FIG. 3. In this example a difference was found between the deflavored soy concentrate and the control, but none were at the 95 percent confidence level, although all the values were lower. This is shown in FIG. 4. Also included are the results of a blind control used, which was rated after the deflavored sample. In this case, the blind control was found to have stronger flavor attributes than the original control of FIG. 3. It is believed that this occurred because the blind control in this example was tested after the deflavored sample and appeared to the panel to have a relatively stronger flavor in the second evaluation of the control. However, when compared with the blind control sample, the deflavored sample showed significant differences for three of the flavor attributes at the 90 to 95 percent confidence level, as shown in FIG. 5.

**EXAMPLE 8.** The membrane used to deflavor soy proteins should have a molecular weight cutoff of 10,000 Daltons, shown to be effective in Examples 6 and 7. A higher molecular weight cutoff membrane can be used if desired, but at a molecular weight cutoff of 50,000 Daltons some valuable proteins have been lost in the permeate, as is shown in this example.

Five pounds (2.27 kg) of a dry soy isolate (Supro-670 PTI) was mixed with 95 pounds (43.2 kg) of water as in Example 7 to provide a slurry

containing 5 percent soy solids. 1 N NaOH was added to raise the pH to 11 and solubilize the soy proteins. Diafiltration using five additions of water was carried out in a manner similar to that described in Examples 6 and 7 and using the hollow fiber membranes of Example 6. The pH was maintained at about 9 to about 12 during diafiltration. Samples of the permeate were taken at five minute intervals, neutralized and frozen for protein analysis.

The permeate samples were analyzed for total protein content by electrophoresis, with the results shown in the following table:

TABLE A:

Time (minutes)	Molecular Weight Cutoff	
	10,000 Daltons	50,000 Daltons
	Protein (%)	Protein (%)
0	0	0.4
5	0.6	1
10	0.8	0.6
15	0.4	0.6
20	0.4	0.6
25	0	0.4
30	0	0.4
35	0.5	0.4
40	0	0.3
45	0	N/A

It can be seen that the membrane having a 10,000 Dalton cutoff retains more protein than the membrane having a 50,000 Dalton cutoff. The value at 35 minutes for the 10,000 Dalton membrane is believed to be erroneous.

**EXAMPLE 9.** Samples of soy materials decaffeinated using the methods of Examples 6-8 were analyzed by protein gel electrophoresis. The results indicate that the molecular weight distribution of the retained soy materials

was substantially the same as that of the original soy material. The results are shown in the following table:

TABLE B:

Molecular Weight (KD)	Soy Material							
	Soy Flavor		Soy Isolate		Soy Isolate		Soy Milk	
	Control (%)	De-flavored (%)	Control (%)	De-flavored (%)	Control (%)	De-flavored (%)	Control (%)	De-flavored (%)
>26	74	73	21.7	19.7	22	20	69	71
14-27	18	19	30.8	32.2	31	32	20	21
3.5-14	7	8	47.4	48	45	48	10	9
<3.5	0	0	0	0	0	0	0	0

**EXAMPLE 10.** Analysis were carried out for the chemical constituents associated with the flavor attributes determined by the sensory panels described in previous examples. Two samples of soy protein isolates were tested. One sample had been de-flavored by the method described in Example 7; the second sample had not been de-flavored.

In a first test, one gram of a control sample was diluted with 15 g of water, 2  $\mu$ l of 300 ppm of 4-heptanone was added as an internal standard, and the mixture was purged with 100 ml/min of helium at 60°C for 30 min. A de-flavored sample was prepared similarly as the control sample, except that the pH was raised to 10 by adding a NaOH solution in order to solubilize the proteins. The volatile compounds were analyzed by GC/MS (HP GC5890/MSD5972). The results for various compounds are shown in FIGS. 6 and 7. The de-flavored soy sample contained smaller amounts of the flavoring compounds.

In a second test, three gram samples were diluted with 30 g of water and 2 µl of 300 ppm 4-heptanone was added as an internal standard. The resulting mixtures were purged with 100 ml/min of helium at 60°C for 20 min to remove the volatile compounds. The volatiles were analyzed by gas chromatography and the odor of the compounds judged by human criteria. The odors associated with specific chemical compounds are reported in the following table:

TABLE C: Odor Characteristics of Decreased Compounds After Deflavoring Process.

Compound	Odor in SPI Control	Odor in Deflavored SPI
1-pentanol	faint, green	weakly fatty
2-ethylphenol	spicy, herbaceous	ND
1-nitropentane	ND	ND
1-octen-3-ol	mushroom, earthy, very strong	mushroom, earthy, strong
<i>cis</i> -2,4-heptadienal	ND	ND
<i>cis</i> -3-octen-2-one	ND	ND
<i>trans</i> -2,4-heptadienal	ND	weak green
acetophenone	burnt, floral, caramel	burnt, caramel
<i>cis, trans</i> -3,5-octadien-2-one	ND	ND
<i>trans, trans</i> -3,5-octadien-2-one	green, floral, fatty	fatty, green
2,4-nonadienal	fatty, oily, deep-fried	fatty, oily, deep-fried
<i>cis</i> -2,4-decadienal	fatty, oily, musty	green onion, painty
4-(1-methylpropyl)- phenol	bubblegum, fruity	ND
<i>trans</i> -2,4-decadienal	fatty, oily, waxy	fatty, oily, green
2-pentylfuran	green, floral, etherous	green, floral, etherous
<i>trans</i> -3-octen-2-one	floral, green, earthy	floral

**EXAMPLE 11.** Application of soy materials to food products was illustrated by adding deflavored soy material to a Balance Bar® (Kraft Foods) and comparing the flavor with an equivalent Balance Bar® containing the

same soy material, but which had not been deflavored. In one sample all of the soy material was a dry soy isolate (Supro-661 from PTI), in the second sample 50 percent of the soy material had been deflavored by the diafiltration process of the examples and 50 percent was not deflavored. A taste panel  
5 preferred the second sample 8 to 3, scoring 6.11 on a scale of 1-10 (with 10 being the best), versus a score of 3.5 for the first sample.

**EXAMPLE 12.** In a manner similar to Example 6, samples of soy isolate were compared, deflavored according to the process of the invention and the control sample of soy isolate, concentrated in proteins was hydrated  
10 in water to a 10 percent solution. FIG. 9 shows the results found by a trained sensory panel for the control sample. The deflavored sample was compared to the control by the panel, which found, as can be seen in FIG. 10, that many of the characteristic attributes of the control sample had been reduced. However, it was found that the flavor designated oxidized had increased.

**EXAMPLE 13.** Thirty pounds of a soy protein isolate (Surpo™ 710 from PTI) was mixed with 270 pounds water in a tank with high agitation for about 20 to about 30 minutes to hydrate the soy protein. NaOH (1N) was added to adjust the pH to 10. In a similar manner to that described in  
15 Example 7, the soy slurry was subjected to ultrafiltration/diafiltration at 120°F through a spiral membrane (Gea Niro Inc.) having a molecular weight cutoff of 10,000 Daltons; water was added continuously at the same rate as permeate removal and the retentate was recirculated to the tank. The pH was maintained at about 9 to about 12 during ultrafiltration. Ultrafiltration/  
20 diafiltration was continued until the amount of permeate collected was equal to about 5 washes (each wash was about half of the initial starting volume). After completion, the pH of the deflavored soy solution was adjusted to 6.5 by adding 1 percent citric acid. The solid deflavored soy material was collected after spray drying.

**Example 14.** This example illustrates the preparation of high protein  
30 snacks and cereals using the deflavored soy isolate of Example 13. These products delivered about 15 to 18 g protein per serving size (about 30 g).

A first dough sample was prepared containing 34.0 percent deflavored soy isolate, 1.9 percent starch, 56.6 percent water, 0.3 percent salt, 1.9 percent double acting baking soda, and 5.3 percent wheat flour. The dough was prepared by mixing the dry ingredients in a mixer for about 2 minutes and then slowly adding water with mixing over an about 5 minute period. The dough was then kneaded for about 5 minutes. The resulting dough was balled and then flattened using a pasta roller; the resulting flakes were about the size of dimes. The sample was baked for 7 minutes at 400°F to achieve a crisp product which became somewhat chewy upon cooling. No off-flavors were detected.

A second dough sample was prepared starting with the dough from the first dough sample above and having the following formulation: 650 g of dough from first sample; 65 g sugar; and 70 g wheat flour. Thus, the second dough sample had an overall formation as follows: 28.5 percent deflavored soy isolate, 1.6 percent starch, 47.5 percent water, 0.3 percent salt, 1.6 percent double acting baking soda, 12.2 percent wheat flour, and 8.4 percent sugar. The sugar was first blended into the dough, which became sticky. Blending the additional wheat flour into the sticky dough significantly reduced the stickiness. Several different shaped samples were made with the dough as follows: (1) formed dough balls and then flattened (average diameter of about 0.75 inches when flattened); (2) formed large flat sheet (about 12 by about 18 inches; (3) formed small squares (about 0.8 inches on a side); and (4) formed small balls (non-flattened; about 0.3 inches in diameter). Samples were baked in a conventional oven at 280°F for about 12 minutes. Excellent puffed samples were obtained which were light and crispy (slightly crunchy) with no detectable soy flavor.

A third dough sample was prepared by adding about 2 percent soybean oil to the second dough sample. The dough was sheeted (linguine type) and then baked in a conventional oven at 280°F for about 12 minutes. Excellent puffed samples were obtained which were light and crispy (slightly crunchy) with no detectable soy flavor.



**Example 15.** This examples illustrates the preparing of snacks and breakfast cereals having about 10 g protein per 30 g serving size. The deflavored soy isolate of Example 13 was used. A dough having the following formation was prepared:

5	Ingredient	Amount (g)	Amount (%)
	Water	420	47.9
	Deflavored Soy Isolate	181.5	20.7
	Wheat Flour	210.4	24.0
	Baking Powder	4.7	0.5
10	Salt	5.5	0.6
	Sugar	55	6.3

The dough was prepared as in Example 14 and then split into four batches. The first and second batches were formed into flattened circular shapes (about 0.8 inches in diameter). The second batch were prepared in a manner similar to the first batch except that the samples were docked in the center to prevent puffing during baking. The third batch was formed into balls (about 0.25 inches in diameter). The forth batch was cooked in pressured steam cooker for about 20 minutes, cut into about 0.5 inch grits, and then flaked in a roller flaker before baking. All batches were then baked at about 350°F for about 15 minutes.

Samples from batches 1-3 produced very good products which had a very good crunchy texture. Puffed samples (batches 1 and 3) were excellent, forming the desired puffed shapes; the sample from batch 2 was similar except it was not puffed as expected. The sample from batch 4 (pre-cooked dough) was easier to flake than non-cooked dough. All samples provided very good results with a crispy (slightly crunchy) texture which holds up well in milk (i.e., stays crunchy for an acceptable time period – i.e., about 20 minutes as compared to about 5 minutes for most conventional breakfast cereals); the puffed samples floated in the milk.

**Example 16.** The samples from Example 15 were topically flavored to product a wide variety of snacks and breakfast cereals by spray coating the baked pi ces with vegetable oil and then tumbling with the desired spices and flavors. Spices and flavors included the following: (1) pizza spice blend; (2) Italian savory (garlic, oregano, parsley, salt); (3) Mexican spice blend; (4) sugar glaze (candy type); (5) icing sugar; and (6) cocoa and icing sugar blend. All products had excellent taste profiles with no off flavors and were crispy and airy. The puffed type products floated in milk an did not get soggy for over 20 minutes as compared to conventional breakfast cereals.

**Example 17.** This example demonstrates the preparation of pizza dough prepared with deflavored soy isolate from Example 13 and having the following formulation:

Ingredient	Amount (g)	Amount (%)
Water	420	46.9
Deflavored Soy Isolate	182	20.3
Wheat Flour	210	23.4
Baking Powder	4.7	0.5
Dry Yeast	4.0	0.4
Salt	5.5	0.6
Sugar	40	4.5
Vegetable Oil	30	3.4

Dry ingredients were blended in the Hobart mixer for about 5 minutes, at which time water and oil were slowly added and mixing continued for about 10 minutes to form the dough. The dough was sheeted and then baked at 450°F for 12 minutes. Final baked pizza dough had excellent texture and flavor. No off flavors were detected.

**Example 18.** This example demonstrate the preparation of chocolate chip cookies using the deflavored soy isolate of Example 13 and having the following formulation:

	<b>Ingredient</b>	<b>Amount (g)</b>	<b>Amount (%)</b>
	Deflavored Soy Isolate	95	17.2
	Soft Wheat Flour	95	17.2
	Shortening	120	21.7
5	Granulated Sugar	50	9.0
	Brown sugar	50	9.0
	Liquid eggs	90	16.2
	Salt	2	0.4
	Sodium Bicarbonate	5	0.9
10	Chocolate Chips	47	8.5

The dough was prepared by melting the shortening with both the granulated and brown sugars. After cooling the mixture to room temperature, the liquid eggs were blended into the mixture to form a melted blend. The dry ingredients were mixed in a Hobart mixer for about 5 minutes. The pre-melted blend was then added to the dry ingredients and mixing continued for about 10 minutes. The resulting dough was formed into balls, placed on a cookie sheet, and then baked at 350°F for 17minutes.

The resulting chocolate chip cookies were considered excellent with a very moist mouth feel with no soy flavors. Each cookie (about 20 g) would provide about 3 g protein.